CELIAC DISEASE AND NUTRITION STATUS AMONG THOSE FOLLOWING A GLUTEN-FREE DIET

A Thesis

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Abstract

The prevalence of celiac disease is increasing and the popularity of the gluten-free diet—the only current medical treatment for celiac disease—is also increasing. However, the number of individuals following a gluten-free diet (GFD) is highly disproportionate to the number of individuals with diagnosed celiac disease. This raises the questions: who is following the GFD and what are the reasons for following the diet outside of a diagnosis of celiac disease? Previous research has demonstrated that the GFD lacks essential nutrients such as fiber, iron, B vitamins and folate, so there is concern that following a GFD without celiac disease may not only be unnecessary, but may also be have more risks than benefits. This study aimed to describe the population following a GFD, demographically and nutritionally. Using data from the 1999-2004 and 2009-2010 NHANES surveys, conducted by the Center for Disease Control and Prevention (CDC), demographic data, medical history questionnaires and serological test results were collected for 157 individuals who were following a GFD, who had ever been told they had celiac disease and who had either a single or double positive serological test for the celiac antibodies tTG and EMA. The descriptive analyses of this population revealed that Non-Hispanic white women (average age of 49 years) are the most likely followers of the GFD. Also, of those following a GFD, >90% were doing so without ever being told they had celiac disease. Nutritionally, those following a GFD consumed a higher average amount of fiber, iron, folate and riboflavin than those not following the diet. However, the percentage meeting the EAR/AI thresholds for these specific nutrients is lower for those following a GFD than for those who are not. Further research on the adequacy of the GFD is needed as the gluten-free product market continues to evolve.

Problem Statement

The prevalence of celiac disease, an autoimmune disorder which damages the gastrointestinal tract, is increasing and it is estimated that 1 in every 133 people in the United States is affected (1). Diagnosis of this disease presents many new challenges, but arguably the most difficult lifestyle change is adherence to a gluten-free diet. Currently, this is the only treatment for celiac disease, so it is essential that people with celiac have an in-depth understanding of the foods they can and cannot eat. For individuals with celiac, the consequences of eating foods that contain gluten include bloating, diarrhea, abdominal pain, and cramping but also more severe symptoms such as peripheral neuropathy, seizures, skin rash and mouth ulcerations. Ultimately, if persons diagnosed with celiac disease do not restrict gluten, their nutritional status will decrease and there is an increased chance of complications from malabsorption.

Considering that persons with celiac have no option other than to follow a gluten-free diet, examining and improving the nutritional adequacy of the diet is pertinent to maintaining good overall health in these individuals. Previous studies have concluded that persons following a gluten-free diet are more likely to be deficient in iron, fiber, B vitamins and grains than those consuming a normal diet (2, 3). Possible explanations for these deficiencies include overall decrease in consumption of grains and lack of fortification in gluten-free foods. Many people meet their daily requirements of iron, fiber and B vitamins with enriched cereals, breads and pastas—foods that are restricted within the gluten-free diet.

Most recently, it appears that more and more individuals without a diagnosis of celiac are choosing to eliminate gluten from their diet. This could have serious

implications on their overall health. It is important to understand more about these individuals who choose a gluten-free diet so that proper knowledge about how to meet their nutritional needs from gluten-free foods can be provided.

Review of Literature

Celiac disease (CD) is a chronic, complex disease affecting nearly 1 in every 133 people in the United States and approximately 1% worldwide (1, 4). According to the CDC, this prevalence is higher than other well-known diseases such as ulcerative colitis, cystic fibrosis and Crohn's disease (5). Women, people of European descent, and individuals under the age of sixty present with a higher rate of celiac, as well as those who are first or second-degree relatives of people with the disease (1). Currently, the only treatment for this disease is medical nutrition therapy and adherence to the gluten-free diet (4).

Overview of Gluten

Gluten, a storage protein found mainly in wheat, rye and barley, is responsible for the damage to the intestinal mucosa in people with celiac disease. When the small intestine is exposed to prolamins, the functional unit of gluten, there is a toxic and inflammatory response which leads to damage of the enterocytes (4). Loss of digestive enzymes and decreased surface area for absorption are two results of this adverse response and lead to the symptoms of celiac disease—diarrhea, bloating, gas production, abdominal pain and malabsoprtion (4). Eliminating gluten from the diet is currently the primary treatment for celiac, but, considering the numerous foods which contain gluten, this is easier said than done.

Not only is gluten found in wheat, rye and barley products as mentioned above, but also in some vitamins and minerals, lip balms and even medicines (6). The scope of products that contain gluten can be overwhelming to a newly-diagnosed celiac patient as gluten is found in breads, cereal, pasta, potato chips, candy, pastries, gravies, soups, hot dogs and even some cold-cut meats (6). Catassi et al (7) found that as little as 50 mg of gluten per day for three months can result in intestinal damage—this is the amount of gluten in approximately $1/100^{th}$ of a slice of bread (7). With the vast array of foods that contain gluten and the extremely small amount of gluten that can cause adverse symptoms, it is understandable why the adherence rate for the gluten-free diet in celiac patients is generally low (8).

Celiac Disease

Genetics play a crucial role in the development of celiac disease, as the HLA-DQ2 and HLA-DQ8 genes are present in 95% of people with the disease. However, this genotype is present in other individuals who never present with the signs or symptoms of celiac; therefore, we can conclude that an environmental trigger is responsible for the onset of the clinical manifestations (9). Possible environmental factors include method of birth, season of birth, length of breastfeeding, age at which gluten is introduced, and frequency of infections during early childhood (4, 10).

As previously discussed, the ingestion of gluten causes an inflammatory response and the markers of this immune response can be helpful in the diagnostic procedure for celiac disease. The antibodies produced include IgA anti-tissue transglutaminase (anti-tTG), endomysial IgA (EMA) and anit-gliadin (AGA), with anti-tTG being the most commonly used in diagnostic testing. However, the gold standard for diagnosing celiac

involves an intestinal biopsy to confirm the presence of enteropathy (4, 10). Indications of villous atrophy, or the flattening of the hair-like structures on the surface of the mucosa, and crypt hyperplasia, the overproduction of intestinal cells, are commonly found in the biopsies of people with celiac disease (4).

Depending on the severity of the villous atrophy and the amount of the gastrointestinal tract which is affected, individuals with celiac disease may experience symptoms such as cramping, abdominal pain, diarrhea and gas production. Also, celiac disease can cause adverse effects to other parts of the body including bone or joint pain, numbness in the legs, ulcers in the mouth and itchiness and blisters on the skin known as dermatitis herpetiformis (12). While these are the common symptoms of celiac disease, some people may not experience any of the classical symptoms, but instead present with problems such as iron deficiency anemia, infertility, osteoporosis, unexplained weight loss, and short stature (9, 12). These individuals are classified as having "silent" or "latent" celiac disease and test positive for certain antibodies, but show no evidence of villous atrophy or other intestinal damage (12).

Because celiac disease is an autoimmune disorder, people with the disease are at a higher risk for other autoimmune disorders such as type 1 diabetes mellitus, thyroid disease, rheumatoid arthritis, intestinal cancer and non-Hodgkin's lymphoma (4, 12). According to Ciacci (13), the risk for intestinal cancer increases almost ten-fold in people who leave their celiac disease untreated. Along with increased risk for other medical disorders, patients with celiac are at a higher risk for nutritional deficiencies as well (13). Many of these deficiencies are directly related to the damage of the mucosa and reduced surface area for absorption, but other nutrition deficits stem from the person's reduced

intake of foods with gluten. A closer look at the gluten-free diet sheds light on the vitamins and minerals it is lacking.

The Gluten-Free Diet

As previously mentioned, gluten is found in a countless number of foods and eliminating it from the diet requires careful investigation of every food a person consumes. Products containing wheat, barley and rye are eliminated and some research suggests that oats should also be restricted (2). Certain people with celiac are sensitive to the prolamin in oats, but more importantly, oats may be contaminated with other gluten-containing products during processing and distributing. Because we know that only a small amount of gluten is needed to harm the intestinal tract of a celiac patient, the need for detailed labeling on all products that possibly contain gluten is significant.

Currently, the FDA requires that the term "gluten-free" only be applied to foods with less than 20 parts per million (ppm) of prolamin (12). Establishing a standard amount is pertinent in order to provide people with celiac disease accurate and reliable information as to not endanger their health through mislabeling. Because gluten may be present in other products such as medications, contacting the manufacturer is currently the best practice for confirming that the product is safe for consumption.

A study performed by Thompson et al. (14) analyzed 22 inherently gluten-free products without a gluten-free label to see if they contained gluten. The findings revealed that comingling of grains is very common as seven of the 22 products would not meet the FDA's guideline of <20ppm. Labels such as "this product was packaged using equipment that also packages wheat" are currently not required by the FDA, but are voluntarily placed on foods by the manufacturers. Foods labeled "gluten-free" tend to be more

expensive, possibly from the increased production costs, but the safety of knowing they are actually gluten-free is worth the extra money when one's health is in question (14).

As far as the nutritional quality of the gluten-free diet, grain consumption and the vitamins and minerals found in grains are significantly impacted. Another study by Thompson et al. (3) looked at the adequacy of grain, fiber, iron and calcium in the diets of those with celiac disease and found that women, especially, are not meeting the recommended daily amounts for these nutrients. Because of the damage to the intestinal tract in celiac disease and subsequent lactase deficiency, lactose intolerance is common for recently diagnosed celiac patients. The decreased intake of dairy products then leads to a deficiency in calcium and increases the risk for osteoporosis, especially in women. Less than one-half of the female respondents consumed the recommended amounts of fiber and iron, while less than one-third consumed adequate calcium. Sixty-three percent of males in the survey consumed the recommend six to eleven servings of grain per day, whereas only twenty-one percent of females did. Possible explanations for this deficit include the limited selection of grains without gluten, the majority of gluten-free grains made from refined starch and the lack of enrichment in gluten-free foods. Pastas, cereals and breads are commonly enriched with fiber, B vitamins and iron; however, gluten-free products are usually not fortified, which makes it difficult for people following a gluten-free diet to receive adequate vitamins and minerals (3).

Research on the affects of substituting alternative grains into the gluten-free diet revealed that the source of grain at meals is commonly rice (44% of the time), and some people with celiac simply omit grains from their meals altogether (38% of the time) (2). This pattern left the participants in the study lacking in protein, iron, calcium and fiber;

however, by including three alternative grains per day (oats, high fiber gluten-free bread and quinoa), the same participants showed a significant increase in their daily consumption of these essential nutrients. Because the gluten-free diet is the only present treatment for celiac disease, these nutritional deficiencies call for immediate attention and further research on how to fortify gluten-free grains to the same standard as other grains.

Followers of the Gluten-Free Diet

The gluten-free diet (GFD) has become a well-known diet over the past decade and gluten-free products have exceeded almost $1 billion in sales as of 2009 (10). This statistic, however, seems to conflict with the data on the number of people with celiac disease who adhere to a gluten-free diet (8). Who are the consumers fueling this exponential sales rate of products labeled as "gluten-free?" Several studies have suggested that eliminating gluten from the diet can reduce symptoms of other intolerances or diseases such as irritable bowel syndrome, wheat allergy, and autism (10, 11). While following the GFD for these reasons may have actual health benefits, one current concern is that people are following this diet just as they would follow any other 'fad' diet—with hopes of losing weight and becoming "healthier" (10). Clearly, from the Thompson studies mentioned earlier, there are nutrition concerns with the GFD and it is not just another strategy for someone who is trying to lose weight.

When aiming to understand the motive behind adherence to the GFD without diagnosis of celiac disease, it is important to examine the research of the possible benefits of eliminating gluten. People with a wheat allergy may be common consumers of gluten-free foods, although they need not restrict foods with oats, rye and barley. Gluten-sensitivity is a term describing those people who have an adverse reaction to gluten

without the diagnostic criteria for celiac disease or wheat allergy (10). Both gluten-sensitive and wheat allergy individuals have cited improvements in their symptoms of bloating, gas production and abdominal pain when adhering to a gluten-free diet (10, 11).

Irritable bowel syndrome (IBS) is one of the most common complaints among adults and has been shown to have reduced symptoms when following a gluten-free diet (10). IBS and celiac disease can coexist in the same patient and, quite often, patients with undiagnosed celiac complain of IBS-like symptoms. Because the signs and symptoms of these two disorders are so similar, patients with celiac disease are commonly misdiagnosed with IBS. No matter the diagnosis, people with bloating, abdominal pain, diarrhea and constipation have seen improvements while adhering to the GFD and this may partly explain the increasing demand for gluten-free products (10).

While the GFD has been shown to improve symptoms of other gastrointestinal disorders, it may also improve attention span, social interaction and brain maturation in people with autism (10). One study by Knivsberg et al. (15) argues that undigested gluten breaks down into peptides which can then interfere with signal transmission and lead to an exacerbation of the symptoms of autism. When combined with a casein-free diet, the GFD was found to reduce the "social isolation" and "bizarre behavior" of people with autism who participated in a small study in 2004; however, the evidence backing these conclusions is limited and further research is needed to define the connection between the GFD and autism (10).

Costs of the Gluten-Free Diet

For patients with celiac disease, there is really no question as to whether or not they should follow a GFD, but those people who are choosing to eliminate gluten from

their diet have to weigh the costs and benefits. One of the biggest drawbacks is that gluten-free food is expensive—almost 240% more expensive than comparable wheat-based products (16). Lee et al (16) looked at the cost of gluten-free products versus wheat-based products and found that not only were gluten-free items more expensive, but they were also more difficult to find. Along with this, restricting gluten may make social situations, such as dining out, uncomfortable or stressful. A survey of 253 people with celiac disease indicated that following a gluten-free diet had negative impacts on dining out, traveling and family (16).

The previous costs are more recognizable for people following a gluten-free diet because there is tangible evidence (spending more money) or emotional stress (embarrassment when dining out) associated with the diet. Dangerously, one of the largest impacts of the gluten-free diet is seemingly invisible until it becomes a major concern. Deficiencies in iron, calcium, fiber and other vitamins do not have major effects on one's day-to-day life, but they lead to larger problems such as anemia and osteoporosis (3). Until requirements for fortification of gluten-free foods are developed and other options for obtaining these nutrients are easily accessible, following a gluten-free diet should be used solely for medical nutrition therapy and carefully supplemented with the missing nutrients.

Objectives & Hypotheses

Research Question: What are the similarities and differences of individuals following a gluten-free diet who have a diagnosis of celiac disease versus those who do not?

Objective 1: To determine the characteristics of the population that is following a gluten-free diet.

Objective 2: To identify the nutritional characteristics of individuals following a gluten-free diet.

Data Source

To assess the population following a gluten-free diet, data from the National Health and Nutrition Examination Survey (NHANES) will be analyzed. The National Center for Health Statistics (NCHS), a part of the Center for Disease Control and Prevention (CDC), conducts a series of interviews and physical examinations on a representative sample of about 5,000 people per year in hopes of obtaining vital health statistics about the nation. Originating in the 1960s, this survey has been used to determine the prevalence and risk factors for major diseases and continues to be a reliable resource for health sciences research.

The interview portion of NHANES includes demographic, socioeconomic, dietary and health-related questions, while the physical examination consists of medical, dental, and physiological exams as well as laboratory tests. Initial interviews are conducted in the home and further testing is performed by trained health professionals in mobile examination centers (MEC, Figure 1). In this study, data collected from 1999-2004 and 2009-2010 will be used to examine demographics, dietary recalls, medical conditions and celiac markers in the representative sample.

Figure 1: Mobile Examination Center

Data Collection

The demographics information was collected during the in-home interviews by trained interviewers using the Computer-Assisted Personal Interviewing (CAPI) system.

This system uses consistency checks and alerts for unusual data to ensure the accuracy of the data entry and lessen the burden on the respondent. Participants 16 years of age and older were interviewed directly, while those under the age of 16 and those who could not answer the questions themselves were assisted by a proxy. The participant was able to select the language of the interview (English or Spanish) or request a translator, and hand cards that showed response categories were available for use. Information collected included, but was not limited to age, gender, race, education, marital status, citizenship, years of U.S. residence, household and family income, pregnancy status and military status.

All NHANES participants are eligible for two dietary recall interviews—one collected in person at the MECs and one collected over the telephone 3 to 10 days later. Through these interviews, data was collected on the types and amounts of foods and beverages the person consumed in a 24 hour period. This data was then analyzed for energy and nutrient content. Following the 24-hour recall, participants were asked if this represented a usual daily intake and if they were following any special type of diet. During the interview, measuring guides such as glasses, bowls, spoons, rulers, bean bags, circles and thickness sticks were available to provide a more accurate estimate of portion size.

Similar to how the demographic data was collected, information on medical conditions was collected through in-home interviews by trained interviewers using the CAPI system. These questionnaires cover a broad range of medical conditions for both children and adults, but this study focuses only on the information reported about celiac disease.

In order to determine the prevalence of celiac disease, serum specimens were collected from participants and sent to the Mayo Clinic in Rochester, Minnesota for testing. A two-step serological test is required for the detection of IgA antibodies to tissue transglutaminase and endomysial antibodies of the IgA subclass. Only participants 6 years of age and older were tested. These tests are not considered reliable in children under the age of 6. Because diagnostic testing for celiac disease is still being refined, reliable population estimates of the disease will require four to six years of data collection.

Sample

The population examined in this study includes 157 individuals of various ages, excluding women who were pregnant or lactating.

Data Preparation

Due to the small sample size and nature of the investigation, we used descriptive analysis techniques to organize the data. The NHANES data from 1999-2004 and from 2009-2010 provided the serological testing group, which separated our sample into a TTG negative group, a TTG positive group and a group who were both TTG and EMA positive. The NHANES data from 2009-2010 provided the medical history data and allowed us to describe our population as either 'following a gluten-free diet' or 'not following a gluten-free diet' and 'ever been told you had celiac disease' or 'never been told you had celiac disease.'

Once this organization of data occurred, we were able to analyze the different groups for their intakes of total calories as well as vitamins and minerals of concern with the GFD. These include iron, folate, thiamin (B1), riboflavin (B2), niacin (B3) and fiber.

NHANES provides the raw intake of these vitamins and minerals, but our study calculated the percent daily value by dividing the raw intake by the estimated average requirement (EAR) or the adequate intake (AI) of the micronutrient and multiplying by 100.

% daily value = (raw intake/EAR or AI) x 100

In order to control for the amount of calories an individual consumes and the affect that could have on his or her intake of vitamins and minerals, energy-adjusted nutrients were calculated using the following equation:

Energy-adjusted nutrient = (raw intake/total kcal) x 1000

These various analyses will provide data to gain a better understanding of the nutritional status of those individuals following a gluten-free diet.

Facilities and Equipment

The laboratory and computer in Atwell Hall at the Ohio State University were used to perform this study. SPSS predictive analysis software was utilized for analysis of the data.

Results

For this study, men, those of European descent and those under the age of 60 were the most likely to have a double positive serological test result for celiac disease. The double positive serological testing group was 57% male and 43% female, 90% Non-Hispanic White and had an average age of 45 years old. For those in the medical history sub-group, however, the majority of those who had been told they had celiac disease were women (57% vs. 43%) and 57% of those following a gluten-free diet were also women. For those who had been told they had celiac disease, 36% were Non-Hispanic White, 29% were Non-Hispanic Black and 21% were Mexican American. Similarly, followers of

the gluten-free diet were 37% Non-Hispanic White, 27% Non-Hispanic Black and 17% Mexican American. The average age for the "ever been told you had celiac" sub-group was 57 years and for the "following a gluten-free diet" subgroup, it was 49 years.

Through comparing the responses to the medical history questionnaire and the results of the serological tests, there is an inconsistency with the diagnosis of celiac disease (Table 1). Of those who had been told they had celiac disease, only 7% had a double positive blood test for the disease. Another 7% were single positive and the greatest majority (85.7%) was negative for the celiac antibodies.

	Celiac (double +)		TTG+		TTG -	
	N	%	N	%	N	%
Been told you have celiac disease	1	7.1%	1	7.1%	12	85.7%
On a gluten-free diet	1	1.8%	1	1.8%	53	96.4%

Table 1: Percent with previous diagnosis of Celiac Disese or following a gluten-free diet by serologic profile

A large number of people are following a gluten-free diet without a serological test indicating celiac disease (Table 1). Of those in the medical history sub-group, >90% of the respondents were following a gluten-free diet without ever being told they had celiac disease (Figure 2). Similarly, 96.4% of those in the serological testing sub-group who were following a gluten-free diet had no biochemical markers to indicate the need for the gluten-free diet. Only 1 person in the serological testing sub-group who was following a gluten-free diet actually had the positive antibody markers for both TTG and EMA.

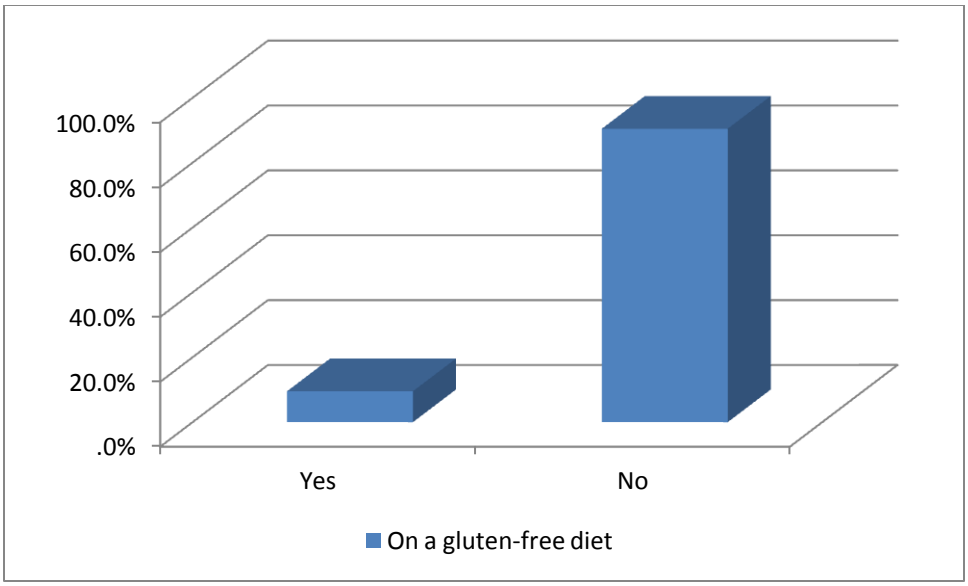

Figure 2: Percent following a gluten-free diet who have ever been told they had Celiac Disease

Through an analysis of the nutrient intakes of those following a gluten-free diet and those who are not, this study shows that individuals following a gluten-free diet consume an average of 300 calories less per day than those not following the diet (1896 kcal vs 2214 kcal). Data from other studies seems to be inconclusive on this matter, with some showing weight gain for those on a gluten-free diet (17, 18).

Using the energy-adjusted nutrient values for further comparison of specific nutrients provides the most accurate picture of the adequacy of the gluten-free diet (Table 2). In this sample, those following a gluten-free diet actually consumed higher amounts of the following nutrients: fiber (10.17gm vs. 7.75gm); thiamin (0.82mg vs. 0.78mg); riboflavin (1.06mg vs. 1.04mg); iron (8.44gm vs. 7.57gm) and folate (281.26mcg vs. 266.82mcg). The only nutrient that was lower for those following a gluten-free diet versus those who were not was the nutrient, niacin (12.19mg vs. 12.32mg). With the rising popularity of the gluten-free diet over the past decade, the variety and quality of

gluten-free products has improved, making it easier for those following the diet to reach their necessary requirements for vitamins and minerals each day (17).

	Celiac Disease Serum Assay		Following a gluten-free diet?	
	Celiac (double +)	TTG+	Yes	No
Nutrient	**Mean**	**Mean**	**Mean**	**Mean**
Raw intakes				
Energy (kcal)	2194	1848	1896	2214
Dietary fiber (gm)	17.88	13.94	18.69	15.87
Thiamin (Vitamin B1) (mg)	1.78	1.44	1.48	1.71
Riboflavin (Vitamin B2) (mg)	2.47	1.80	1.89	2.25
Niacin (mg)	27.65	20.76	21.17	26.81
Iron (mg)	17.38	12.61	14.80	16.25
Folate, DFE (mcg)	593	446	502	576
Percent of EAR/AI				
Dietary fiber (gm)	65.28	53.36	69.52	59.54
Thiamin (Vitamin B1) (mg)	198.73	153.27	167.81	191.88
Riboflavin (Vitamin B2) (mg)	261.03	178.22	209.52	239.86
Niacin (mg)	250.67	181.76	197.73	245.08
Iron (mg)	299.94	215.14	261.26	274.98
Folate, DFE (mcg)	198.12	142.97	171.55	192.71
Energy-adjusted (per 1,000 kcals)				
Dietary fiber (gm)	8.75	7.71	10.17	7.75
Thiamin (Vitamin B1) (mg)	.85	.77	.82	.78
Riboflavin (Vitamin B2) (mg)	1.16	.99	1.06	1.04
Niacin (mg)	12.68	11.46	12.19	12.32
Iron (mg)	8.21	6.89	8.44	7.57
Folate, DFE (mcg)	287.90	239.96	281.26	266.82

Table 2: Nutrient intake and nutritional adequacy by serologic profile and those following a gluten-free diet

While the mean consumption of fiber, thiamin, riboflavin, iron and folate is higher for those following a gluten-free diet than the mean for those who are not following a gluten-free diet, the percentage of people meeting their EAR/AI thresholds is less for those individuals on a gluten-free diet. Table 4 indicates that only 64.4% of those following a gluten-free diet are meeting their EAR/AI for thiamin and only 61.0% are

meeting their EAR/AI for folate. Contrastingly, of those not following a gluten-free diet, 86% were meeting their EAR/AI for thiamin and 78% for folate. Of those who had been told they had celiac disease, none were meeting their EAR/AI for fiber, while only 2/3 were meeting their requirements for thiamin and folate. As a whole, this sample revealed an inadequate amount of fiber with those following a gluten-free diet achieving the highest percentage at only 18.6%.

		% Meeting the EAR/AI					
Group	**Category**	**Fiber**	**B1**	**B2**	**B3**	**Fe**	**Folate**
Following a gluten-free diet	Yes	18.6%	64.4%	83.1%	79.7%	84.7%	61.0%
	No	8.0%	86.0%	88.0%	94.0%	92.0%	78.0%
Serum celiac test	Celiac (double +)	12.5%	90.0%	95.0%	95.0%	95.0%	76.3%
	TTG+	6.4%	72.3%	76.6%	80.9%	83.0%	63.4%
Ever been told you have celiac disease?	Yes	0.0%	66.7%	83.3%	75.0%	83.3%	66.7%
	No	15.5%	75.3%	85.6%	87.6%	88.7%	69.1%

Table 3: Percent meeting the EAR/AI for specific nutrients by those following a gluten-free diet, serological profile and those who have ever been told they have Celiac Disease

Specific food groups were also examined in this study (Table 5). Previous studies have concluded that grain consumption (and specifically whole grains) among those following a gluten-free diet is less than those not following a gluten-free diet (2, 3, 9). This study also supports that claim with the mean number of grain ounce equivalents for those following a gluten-free diet being 5.77 and only .68 ounce equivalents of whole grains. For those respondents not following a gluten-free diet, the mean number of grain ounce equivalents was 7.13 and .81 ounce equivalents of whole grains. Interestingly, those following a gluten-free diet consumed, on average, more vegetables (1.40 oz vs. 1.27 oz), more foods from the dairy group (1.87 cups vs. 1.37 cups) and more discretionary oils (14.23gm vs. 10.39gm) than those not following a gluten-free diet.

On the other hand, those following a gluten-free diet consumed less fruit (.86 cups vs. 1.06 cups), less discretionary solid fat (47.23gm vs. 48.19gm) and less added sugars (22.67 tsp vs. 25.96 tsp). This data seems to correspond with the overall lower caloric intake for those on a gluten-free diet, as fats and added sugars can make up a large percentage of the calories that is consumed each day.

As mentioned earlier, the group with the highest percentage meeting their EAR/AI for dietary fiber was the group following a gluten-free diet. Through this in-depth analysis of their specific food intake, we can see that this group's higher consumption of vegetables, cooked dried beans and peas and number of fruit cup equivalents from whole fruit may explain their higher intake of fiber.

	Celiac Disease Serum Assay				Are you on a gluten-free diet?			
	Celiac (double +)		TTG+		Yes		No	
Food Group	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total number of grain ounce equivalents	6.98	3.22	6.08	3.64	5.77	3.79	7.13	3.48
Number of whole grain ounce equivalents	1.20	1.67	.52	.87	.68	1.03	.81	1.16
Number of non-whole grain ounce equivalents	5.79	3.07	5.56	3.58	5.08	3.64	6.32	3.44
Total number of vegetable cup equivalents, excl legumes	1.02	.93	1.48	1.50	1.40	1.26	1.27	.98
Number of dark-green vegetable cup equivalents	.03	.13	.18	.72	.05	.14	.09	.35
Number of orange vegetable cup equivalents	.07	.20	.07	.17	.08	.23	.09	.21
Number of white potato cup equivalents	.30	.51	.40	.61	.43	.82	.31	.39
Number of other starchy vegetable cup equivalents	.05	.12	.09	.21	.06	.15	.09	.16
Number of tomato cup equivalents	.23	.37	.23	.34	.31	.49	.28	.40
Number of other vegetable cup equivalents	.33	.39	.51	.92	.47	.64	.41	.52
Total number of fruit cup equivalents	1.22	1.18	1.09	1.43	.86	1.09	1.06	1.08
Number of citrus, melon, berry cup equivalents	.65	1.01	.36	1.09	.33	.64	.42	.75
Number of other fruit cup equivalents	.56	.86	.73	1.06	.53	.80	.64	.94
Total number of milk group (milk, yogurt & cheese) cup equivalents	1.25	1.00	1.82	1.75	1.82	1.57	1.37	1.01
Number of milk cup equivalents	.91	.95	1.38	1.59	1.29	1.43	.96	.92
Number of yogurt cup equivalents	.00	.00	.01	.07	.00	.00	.01	.07

Number of cheese cup equivalents	.33	.33	.43	.46	.52	.70	.39	.38
Oz equivalents of lean meat from soy product	.10	.51	.02	.08	.01	.05	.07	.44
Oz equivalents of lean meat from nuts and seeds	.25	.64	.28	.70	.29	.81	.38	.96
Number of cooked dry beans and peas cup equivalents	.13	.30	.12	.31	.27	.76	.14	.34
Grams of discretionary Oil	9.64	10.81	10.93	12.01	14.23	18.77	10.39	10.61
Grams of discretionary Solid fat	47.36	28.71	51.19	35.28	47.23	26.66	48.19	26.54
Teaspoon equivalents of added sugars	26.41	20.24	26.61	22.68	22.67	24.25	25.96	19.08
Number of fruit cup equivalents from juice	.61	.97	.41	.58	.26	.39	.48	.79
Number of fruit cup equivalents from whole fruit	.57	.86	.63	1.30	.56	.89	.53	.85

Table 4: Consumption of different food groups by serological profile and those on a gluten-free diet

Discussion

This study quantitatively describes the current popularity in the United States the gluten-free diet. It is not unusual to see the term 'gluten-free' being used as the new buzzword for healthy eating. A recent survey reported that the number one reason consumers cite for buying gluten-free products is the perception that they are healthier than comparable foods with gluten (19). While gluten-free products are essential for those with celiac disease or gluten sensitivity, there is little evidence to support that a gluten-free diet is beneficial for those without a medical need (3, 17). New research has shown that gluten itself provides health benefits and eliminating it from the diet may do more harm than good (17).

As mentioned previously, sales of gluten-free foods reached over $1 billion dollars in 2009 (10). However, new projections expected approximately $2.6 billion dollars worth of gluten-free sales in the year 2012 (17). This rapid rate of growth for the gluten-free market is alarming because it does not correlate with the rate of diagnosis of celiac disease. This study alone showed that 90% of the respondents were following a

gluten-free without ever being told they had celiac disease. While this is an extremely high percentage, we cannot rule out that some may be following it for other medical reasons such as gluten sensitivity, irritable bowel syndrome, wheat allergy or autism (10, 11). It is the percentage of respondents who are following a gluten-free diet because they think it is a new weight loss solution or simply because they perceive it to be healthier that raises concerns.

While this study showed gluten-free diet followers consuming an average of 300 less calories per day, there is no published evidence that the gluten-free diet leads to weight loss in patients without celiac disease or gluten intolerance (17). Patients with celiac disease who strictly adhere to the diet have shown improvement in their body mass index (BMI) status, but this is not always the case. Two different studies of adults with celiac disease who followed a gluten-free diet for at least 2 years showed that initially overweight or obese patients actually gained weight on the diet—27% of adults in the first study and 82% of adults in the second (17, 18). A common misconception is that gluten-free products are lower in calories and/or fat. In reality, several gluten-free products are actually higher in calories and fat than their gluten-containing counterparts (17). For example, one serving of regular pretzel sticks has 110 calories and 1 gram of fat, whereas one serving of gluten-free pretzel sticks has 120 calories and 4 grams of fat (myfitnesspal.com20).

Of those following a gluten-free diet, a lower percentage of people were meeting their EAR/AI value for niacin, thiamin, riboflavin, folate and iron than people who were not following the diet. Previous studies have shown that the gluten-free diet is low in iron and B vitamins (2,3) and a recent study in Australia analyzed the diets of people with

celiac disease at different stages—pre-diagnosis, 12 months post-diagnosis and >2 years post diagnosis (18). This study found that the proportion of women with inadequate mean dietary intakes of thiamin, folate, iron and fiber increased between pre-diagnosis and >2 years post diagnosis. For men, only thiamin had a greater proportion with inadequate mean dietary intake at >2 years post-diagnosis than at pre-diagnosis. It is essential for Registered Dietitians and other health professionals to know what nutrients are likely to be deficient with the gluten-free diet so that the most accurate education can be provided to patients following the diet.

One recommendation for patients on a gluten-free diet may be to add a supplement that provides the vitamins and minerals they need; however, it would be more ideal to educate patients on the foods they can consume that will provide the same level of nutrients. A positive result of the popularity of the gluten-free diet in recent years is that manufacturers are providing more variety and better quality of foods without gluten (17). While a previous study from 2005 showed glaring deficiencies in the gluten-free diet, this present study and other recent research has demonstrated that the gluten-free diet has improved in nutrient quality (17, 18).

While the initial concern with the gluten-free diet was the lower levels of vitamins and minerals in the diet, current research suggests that it is the actual absence of gluten that could be a concern. Ten healthy subjects followed a gluten-free diet for one month and the levels of beneficial gut bacteria significantly decreased (17). Another study examined the effect of wheat fiber, gluten and bran consumption on serum triglyceride levels. Only the group of subjects who consumed the high gluten diet showed a significant decrease of 13% in their serum triglyceride levels. A third benefit of gluten

may be related to its high content of glutamine, an amino acid that boosts the immune system, prevents infection and supports the integrity of the gut (17, 21). Because the results of this study and several other studies show a decreased consumption of whole grains for those following a gluten-free diet, they are also missing out on the health benefits of whole grains—increased beneficial gut bacteria and reduced blood pressure (2, 3, 17). Adequate fiber consumption from other sources (dry beans, fruits and vegetables) is absolutely necessary when following a gluten-free diet because one of the main sources of fiber in the America diet is wheat-containing breakfast cereals.

Considering that 85% of those who were told they had celiac actually tested negative for the celiac antibodies, there is concern about the reliability of our current system for diagnosing the disease and the standards which health professionals are following. Over the past 30 years, the diagnostic tests for celiac disease have greatly evolved. Not until 1997 was tTG determined to be the major indicator for celiac disease (22, 23). Shortly thereafter, tests for anti-tTG antibodies were developed and have been widely used since. While the duodenal biopsy has been used for many years and is still the current gold standard, the specificity and sensitivity of serological testing is greatly improving (4, 10, 22). A recent study summarized the research evidence from 2004-2009 and concluded that the high sensitivity of the anti-tTG and EMA serological tests would correctly diagnose celiac disease without the need for a duodenal biopsy (24). Eliminating the biopsy would decrease costs and reduce the burden on the patient when seeking a diagnosis, but further studies need to be conducted to support this change in standards (24).

Until this change occurs, however, it is important to address the discrepancies over the technique of the biopsy—specifically where to take the samples from and how many of them to take. According to a recent study, it is best to take 4-6 specimens from the duodenum, with at least 2 of the specimens coming from the duodenal bulb. The duodenal bulb is thought to be the most sensitive region because injury and villous atrophy has been found to follow a proximal to distal gradient within the intestines (22).

This same study suggested that even after the person showed a double positive antibody test and evidence of villous atrophy or crypt hyperplasia from the biopsy, the true diagnosis of celiac disease only came if the person's symptoms resolved after following a strict gluten-free diet. Confusion with diagnosis can also occur if a patient starts following a gluten-free diet before serological and endoscopic tests are performed. Because the elimination of gluten is known to decrease inflammation and, therefore, available antibodies in the blood, an individual who has been following a gluten-free diet for a time may appear to be serologically negative for the disease and present with little inflammation in the bowel (22).

With all the strict and extensive procedures it requires, it is not a surprise that we are seeing an inconsistency in the diagnosis of the disease. Also, because the symptoms are very similar to other diseases such as irritable bowel disease, following a gluten-free diet may be one way to discriminate what disease the person is actually presenting with. If the gluten-free diet is used in this way—as a test for disease diagnosis—proper education should be provided to the patient as to not inquire any harmful nutrient deficiencies while following the diet.

Conclusion

A gluten-free diet is essential for persons with celiac disease or gluten sensitivity and may be beneficial for those with other gastrointestinal or autoimmune disorders, but there is no evidence that it is 'healthier' or a weight-loss diet. However, with a large percentage of those following a gluten-free diet having no biochemical markers for celiac disease, there is concern that the gluten-free diet is assumed to be another fad diet. Another concern is the reliability of the current diagnostic standards for celiac disease and the extent to which health professionals are adhering to them. Although extensive, it is pertinent for health professionals to carry out the necessary steps for diagnosing celiac disease because it causes such a life change for the person being diagnosed.

While just a few years ago there was much concern with vitamin and mineral deficiencies with the gluten-free diet, it seems as though the gluten-free diet of 2013 is more nutrient dense than in years past. The demand for gluten-free foods has exponentially increased in the past five years and with this came an increase in the variety and quality of gluten-free products. Following a gluten-free diet can be well-balanced if one takes careful steps to include whole grains and legumes and to limit foods with high fat and sugar content.

Further research on the nutritional adequacy of the gluten-free diet is needed as the gluten-free product market continues to evolve. Also, more in-depth studies on why people are following the gluten-free diet would provide further insight into how the gluten-free diet is viewed by our culture. From these results, dietitians and health professionals could better tailor their education and advice in order to provide patients with evidenced-based knowledge on the subject. The biggest limitation of this study was

the small sample size, so performing this study using NHANES data again in four years would provide a much larger pool of data and, therefore, a more nationally-representative sample.

Currently, there is no evidence that the gluten-free diet has significant benefits for the general population. In fact, there is new research that suggests gluten itself may provide health benefits. More research is needed to confirm these benefits, but further study into all aspects of the gluten-free diet is certainly needed in order to provide the general population with clear, evidenced-based information regarding the diet.

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